Efficacy of HRCT Imaging vs SPECT/CT Scans in the Staging of Malignant External Otitis

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Abstract

Objective. The prognosis of patients with malignant external otitis (MEO) depends on the extent of the inflammatory changes in the temporal bone and skull base. The efficacy of high-resolution computed tomography (HRCT) imaging in accurately assessing the extent of disease is compared with that of single-photon emission computed tomography/computed tomography (SPECT/CT) scan.

Study Design. A clinical chart review was conducted with medical records and radiologic images.

Setting. Tertiary care medical college hospital.

Subjects and Methods. This study involved patients with clinically diagnosed MEO who underwent both modalities of imaging of the skull base. Staging of the disease extent was compared between the imaging systems among patients. Symptom control and survival rates were analyzed with respect to the SPECT/CT staging of MEO.

Results. Out of 28 patients included in this study, 72% had SPECT/CT scans showing higher staging than the HRCT imaging. Four patients had mild uptake (stage 1), and 15 had disease confined to the mastoid/temporal bone, not reaching midline (stage 2). All patients in stages 1 and 2 were surviving with good symptom control. Five patients with petrous involvement reaching midline (stage 3) had persistent symptoms, and all 4 cases with SPECT/CT showing sphenoid involvement and crossing midline (stage 4) died within a year of diagnosis.

Conclusions. SPECT/CT scan is more sensitive than HRCT imaging in detecting the extent of disease and is a better prognosticator for patients with MEO.

Keywords

malignant external otitis, skull base osteomyelitis, computed tomography imaging

Malignant external otitis (MEO), though rare, is a life-threatening disease of the ear and temporal bone. The term malignant external otitis was given by Chandler. Benecke divided MEO into necrotizing external otitis and skull base osteomyelitis (SBO). In SBO, temporal bone and skull base are both involved, and it has a grave prognosis. It is usually a progressive, potentially fatal disease and can give rise to multiple cranial palsies and various intra- and/or extracranial complications. In severe cases, infection may reach the petrous apex, cross the midline, and involve contralateral temporal bone. In the literature, MOE and SBO are used synonymously, as the disease process is the same. However, MOE is often the starting point for the more extensive disease involving the skull base. This also denotes that the SBO originated in the ear and differentiates from central SBO, which often originates in the sphenoid sinus.

MEO often starts as an infection of the soft tissues of the external auditory canal. From here, it can spread to temporal bone and the skull base through the preformed pathways—fissures of Santorini and the tympanomastoid suture line. It can also spread via the venous channels, fascial planes, or dural sinuses.

This condition occurs primarily among elderly patients with uncontrolled diabetes or immune-compromised status. MEO rarely affects nondiabetic patients and immune-competent patients, and in such cases, Aspergillus fumigatus has been commonly isolated. is the most commonly isolated organism, followed by A fumigatus. Atypical cases of malignant otitis externa were

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also reported, caused by organisms such as *Staphylococcus aureus*, coagulase-negative species, and other fungal organisms. At times, no pathogenic organism is cultured.9,10

This condition frequently presents as nonresolving otalgia, which is often blood stained and accompanied by canal wall edema and granulation tissue at the bony-cartilaginous junction—is characteristic of this condition. Histopathologically, this granular swelling consists of nonspecific granulation tissue.11 The patient may also present with neurologic symptoms, such as facial palsy, double vision, aspiration, change in voice, dysphagia, and deviation of the tongue, indicating grave prognosis. The first nerve to be involved is the facial nerve at the stylomastoid foramen. Presence of facial palsy and immune-compromised status adversely affect the prognosis.12

Radiologic as well as radionuclide investigations play an essential role in confirming bone involvement and assessing the extent of the disease in the skull base. The response to the treatment depends on the extent of the disease. Lee et al staged the condition according to radionuclide uptake: minimal uptake (stage 1); uptake confined to mastoid/temporal bone, not reaching midline (stage 2); uptake extending to petrous apex, reaching the midline (stage 3); and uptake extending to sphenoid bone or crossing midline (stage 4).13

The exact assessment of the extent of the disease is needed to plan the course of treatment and counsel the patient regarding the prognosis so that he or she has realistic expectations regarding the treatment outcomes. Repeated gallium scans may help in monitoring the course of the disease and the response to treatment. Laboratory investigations are also helpful in monitoring the progression of the disease. These include erythrocyte sedimentation rate, C-reactive protein, glucose levels, and creatinine levels.14 The erythrocyte sedimentation rate is almost always raised among patients with MEO.6

Radiologic investigations, such as high-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI), are helpful in detecting bony and soft tissue involvement. HRCT imaging needs at least 30% demineralization of the bone to pick up disease. Single-photon emission computed tomography (SPECT) scans may negate this limitation of HRCT imaging.13

Scintigraphy is much more sensitive than radiologic investigations and can detect bone involvement much earlier than radiologic investigations.15 SPECT with 99m-technetium methylene diphosphonate (99m-Tc MDP) detects abnormalities of bone metabolism as early as 24 to 48 hours after the onset of pathology. By 8 days, it is nearly always positive. SPECT imaging is superior to plain radiographic techniques in identifying abnormal bone metabolism.16 SPECT/CT, wherein SPECT is superimposed on computed tomography (CT) images, helps in better localization of the disease.

Although there are diverse studies in the literature indicating that HRCT needs about 30% demineralization to be evident as bone erosion, its impact on the actual staging of the disease was not known in MEO. The objective of this study is to compare the extent of skull base disease as picked up by HRCT imaging versus SPECT/CT scan for each patient with MEO, as done within a gap of 2 weeks.

**Subjects and Methods**

This is a clinical chart review of patients who were clinically diagnosed to have MEO and treated from July 2014 to June 2017 in the Department of ENT–Head and Neck Surgery, Kasturba Medical College and Hospital, Manipal, India, a tertiary care hospital setup. After approval from the institutional ethical committee of Kasturba Medical College and Hospital, the medical records and HRCT and SPECT/CT images of the patients were reviewed. This study included all consecutive cases of MEO, with or without diabetes or an immune-compromised state, available for follow-up of at least 1 year. Per the departmental protocol, the patients with clinically suspected MEO were hospitalized for parenteral antibiotics, and they were counseled to undergo HRCT as well as SPECT/CT, as the combination was found to give better delineation of the extent of the disease in the skull base. HRCT was done in most cases within 2 to 3 days following hospitalization. The 2 imaging modalities were done with a time gap of only few days in most cases, with none beyond a 2-week gap. For some patients who could not afford both imaging modalities, only HRCT was done, but these cases were not included in this study. Patients with a past history of ear disease or otologic surgery were excluded.

The case records of all the patients included in the study were evaluated for pretreatment symptoms, clinical findings, and otomicroscopic findings. Culture and sensitivity reports of the ear swab were evaluated. Histopathologic reports of the biopsy of suspected granulation tissue, if available, were noted.

The radiologists were requested to review the HRCT imaging (1-mm cuts, multiplanar without contrast) of all included patients based on their hospital registration numbers available in the PACS (picture archiving and communication system) and to specifically examine the extent of the bone and soft tissue changes in the temporal bone/skull base. They had no access to the SPECT/CT images and reports that were filed in the medical records.

SPECT/CT imaging was performed at 3 hours after 99m-Tc MDP injection. The dose of the radiopharmaceutical agent was adjusted for the size of the patient and the information required per the Society of Nuclear Medicine’s procedure guidelines for bone scintigraphy.17 The imaging was acquired by a dual-head SPECT-CT Gamma Camera (SymbiaIntevo Excel; Siemens AG, Erlangen, Germany) with a low-energy, high-resolution collimator in our nuclear medicine department. SPECT images were acquired in continuous mode (128 × 128 matrix, 16 frames, and 4.8-mm slice thickness). CT images were acquired with the current modulation CARE Dose 4D setting (130 kV; slice thickness, 3 mm). SPECT images were reconstructed by flash 3-dimensional iterative image reconstruction with the ordered
subset expectation maximization reconstruction algorithm. The CT study was reconstructed with 1.5-mm slice thickness. Finally, reconstructed SPECT/CT images were obtained in the transverse, sagittal, and coronal planes.

All patients were treated by adequate diabetes control and culture-directed parenteral antibiotics—whenever sensitivity patterns were available or ceftazidime (1.5 g) twice a day for 2 to 3 weeks—and later discharged from the hospital with advice to continue either culture-directed oral antibiotics, whenever positive, or quinolones for 4 to 6 months, with monthly review in the outpatient department. Granulation tissue in the bony canal was excised/cauterized as an office procedure for most patients. Surgical treatment for medically nonresponsive patients was limited to cortical mastoidectomy in 3 cases and canal wall down mastoidectomy in 5 cases. Bone chips were sent to rule out a possibility of mucormycosis. On every follow-up, responses to treatment were noted in terms of symptom control and otomicroscopic findings. None of the patients underwent repeat HRCT or SPECT/CT to decide on the end point of antibiotic treatment, although SPECT with gallium scan is recommended. Antibiotics were stopped only on complete symptom control after a minimum of 4 to 6 months of treatment.

In this study, depending on the extent of radionuclide uptake, the SPECT/CT finding was stratified per the prognosis-based classification proposed by Lee et al, which divides the findings into 4 grades.13 For 4 patients, there was mild radiotracer uptake consistent with soft tissue inflammation (stage 1). For 15 patients, there was a focal uptake of radiotracer in the mastoid or temporal bone (Figure 1), but the uptake did not reach the midline (stage 2). Five patients were recorded to be in stage 3, where there was radiotracer uptake in the petrous part of temporal bone reaching the midline but not crossing it (Figure 2). Four patients were assigned stage 4 (Figure 3), where the radiotracer uptake was crossing the midline (Table 1).

SPECT/CT scans showed more bone disease extent compared to the HRCT imaging in 71.4% of the patients (Table 1). Four patients had mild uptake on SPECT/CT scan (stage 1). None of these patients had HRCT changes of bone erosion; however, HRCT of 2 cases had haziness in a few mastoid air cells, indicating inflammatory changes. SPECT/CT scan of 15 patients demonstrated disease confined to mastoid/temporal bone not reaching midline (stage 2). Only forty-seven percent of these cases had evidence of bone involvement in the mastoid/temporal bone; however, in 73% of the cases, HRCT demonstrated soft tissue changes in this region. This relatively good correlation in stage 2 can be attributed to thin intercellular septations in a pneumatized mastoid. Among SPECT/CT stage 3 and 4 cases (9 patients), 1 had HRCT evidence of bone changes in the petrous/sphenoid bone (positive correlation in 11.1% of cases), and 3 patients had soft tissue changes in this region in their HRCT imaging (positive correlation in 33%). This low correlation may be attributed to the dense bone of the petrous and the sphenoid resisting bone erosion in early stages.

None of 9 patients presenting with facial nerve palsy had HRCT evidence of bone erosion of the facial canal, although it did reveal soft tissue changes in the retrofacial cells. Three patients had vagal palsy, and none had bone

Table 1. Comparison of SPECT/CT Staging with HRCT Staging for Correlation.

<table>
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<tr>
<th>SPECT/CT Stage13</th>
<th>Cases (n = 28)</th>
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<th>Soft Tissue Changes</th>
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<td>II: Uptake limited to mastoid and temporal bone, not reaching midline</td>
<td>15</td>
<td>7 (47)</td>
<td>11 (73)</td>
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<td>1 (20)</td>
<td>2 (40)</td>
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<td>IV: Uptake crossing midline</td>
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<td>Overall</td>
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<td>8 (28.6)</td>
<td>16 (57)</td>
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Abbreviations: HRCT, high-resolution computed tomography; SPECT/CT, single-photon emission computed tomography/computed tomography.

*Number of cases with SPECT/CT positive correlation.
Table 2. Clinical and Imaging Details of Cases of Malignant External Otitis in This Study and Their Treatment Outcomes: Comparison of HRCT vs SPECT/CT.

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Abbreviations: Asp, Aspergillus flavus; CKD, chronic kidney disease; COR, correlation; DM, diabetes mellitus; ED, ear discharge; FNP, facial nerve palsy; FU, follow-up; Gr, granulation tissue; HRCT, high-resolution computed tomography; MRSA, methicillin-resistant *Staphylococcus aureus*; N, no; OCNP, other cranial nerve palsy; OT, otalgia; PA, *Pseudomonas aeruginosa*; RT, radiotherapy; SPECT/CT, single-photon emission computed tomography/computed tomography; Y, yes.

*a*Grading of clinical symptoms/signs: 0, no symptom/sign; 1, mild; 2, moderate; 3, severe.

*b*Stage 0-4.

*c*Bone extent 0-4

*d*Soft extent 0-4
Changes in HRCT imaging in the region of jugular foramen. One of these 3 patients later developed hypoglossal palsy too. As the cranial nerve palsy was clinically evident, no imaging was repeated for this patient.

The follow-up period of the surviving patients ranged from 12 to 21 months (mean, 14.29). All patients in stages 1 and 2 were surviving with good symptom control. Five patients with petrous involvement (stage 3) were surviving on their last follow-up, and most had persistent symptoms (Table 2). All 4 cases with SPECT showing sphenoid involvement crossing midline (stage 4) died within a year of diagnosis: 3 died due to aspiration pneumonia, and 1 died following meningitis with sigmoid sinus thrombophlebitis.

Discussion

MEO can be staged clinically depending on the nerve involvement and radiologically depending on the extension of disease on HRCT imaging. Stage 1 includes disease localized to the external auditory canal with or without facial nerve palsy. Stage 2 includes disease involvement of the skull base and/or involvement of multiple cranial nerves. Stage 3 includes intracranial involvement.9 The SPECT/CT finding can also be stratified into 4 stages per the prognosis-based classification proposed by Lee et al, as mentioned in the Results section.13 Studying various prognostic parameters, they found that the only independent predictor of survival was the SPECT staging at presentation.

Clinical and SPECT/CT staging of MEO is important for therapeutic and prognostic purposes. Early detection and prompt treatment are key to successful management of MEO. The diagnosis is based on clinical, laboratory, and imaging findings. No single definitive criterion exists for the diagnosis of MEO; hence, there is often a delay in the diagnosis.18 Current imaging tools include HRCT imaging, MRI, and radionuclide scintigraphy. The combination of radiologic and radionuclide investigations plays a crucial role in the initial diagnosis and follow-up of patients.19 99m-Tc MDP is commonly used in SPECT scan for initial assessment. Gallium scintigraphy is useful in deciding the end point of antibiotic therapy for MOE. However, it may even be used in the initial assessment of the extent of disease.20 But 99m-Tc MDP SPECT/CT scan is cost-effective when compared with gallium scan.

CT is fast and economical in the initial assessment of patients. Fat plane effacement and subtle erosion of cortical bone are the initial findings.21 However, HRCT has limitations. Osteolysis, though a common finding in MEO, is not specific to malignant otitis externa. It can also be associated with many other conditions, such as a benign or malignant tumor or congenital lesions. CT scan also cannot differentiate between inflammatory or neoplastic conditions. Furthermore, for bone erosion to be evident on CT, approximately 30% of bone has to be demineralized. Thus, early bone erosion may not be detectable in CT.19 In the early stages of the disease, when there is less demineralization of bone, bony changes will not be evident, thus giving false-negative results.8 Hence, CT has low sensitivity as the diagnostic modality. In contrast to HRCT, SPECT has a sensitivity of about 90% in the diagnosis of MEO.19

Filippi and Schillaci reported 100% sensitivity of SPECT in detecting the infective focus and a specificity of 78%. Specificity increases when the findings of SPECT and CT are fused (ie, SPECT/CT) which is about 89%.22 99m-Tc MDP used in SPECT scan binds to the bone by chemisorption to hydroxyapatite crystal. The skeletal system takes up

Figure 1. (A) HRCT scan shows no evidence of bone erosion in the left temporal bone, and (B) SPECT/CT demonstrates grade 2 tracer uptake in the temporal bone. HRCT, high-resolution computed tomography; SPECT/CT, single-photon emission computed tomography/computed tomography.

Figure 2. (A) HRCT scan shows bone erosion confined to the right mastoid, and (B) SPECT/CT demonstrates grade 3 tracer uptake in the temporal bone, reaching the midline. HRCT, high-resolution computed tomography; SPECT/CT, single-photon emission computed tomography/computed tomography.

Figure 3. (A) HRCT scan shows no evidence of bone erosion in the right temporal and sphenoid bone, and (B) SPECT/CT demonstrates grade 4 tracer uptake in the temporal bone and sphenoid bone, crossing the midline (B). HRCT, high-resolution computed tomography; SPECT/CT, single-photon emission computed tomography/computed tomography.
about 50% of radiotracer, which occurs after 2 to 6 hours after intravenous injection. Increased uptake of the radiotracer depicts increased bone turnover. This is due to the changes in bone vascularization and/or osteoblastic activity. SPECT/CT can detect the bone abnormality as early as 24 to 48 hours after the onset of abnormality.10,16,23 With the help of lesion:nonlesion ratios on SPECT, a reliable difference can be made between severe cases of otitis externa and malignant otitis externa.24

Lee et al studied 38 patients with cranial base osteomyelitis for the prognostic factors affecting the treatment outcome. They found univariate predictors of survival as SPECT grade, immune compromise status, fungal/mixed infections, Charlson score, and cranial neuropathy.13 Their proposed SPECT-based grading system of SBO accurately predicted the long-term outcomes of these patients.

Chakraborty et al also emphasized that SPECT/CT scan can detect the disease early as compared with CT.25 Chen and Hsieh recommended the use of SPECT/CT as a routine investigation in MEO.15 Sharma et al also suggested the use of SPECT/CT for the diagnosis of malignant otitis externa.26 In our study of 28 patients, SPECT/CT scan was helpful in the diagnosis even when no bone erosion was evident in HRCT imaging. For only 8 patients did HRCT show evidence of bone changes, thus showing poor sensitivity.

Chang et al evaluated the MRI of patients with central SBO without otitis externa, and they found, as a consistent finding for 5 of 6 patients, diffuse clival hypointensity on T1-weighted images due to bone marrow infiltration.27 Diffusion-weighted images help in distinguishing SBO from the malignancy of the skull base by using the apparent diffusion coefficient values of the soft tissue.28 To improve the diagnostic efficacy in SBO secondary to MOE, van Kroonenburgh et al suggested a combination of functional and anatomic images with positron emission tomography–MRI (T1, T2, T1–fat saturation–gadolinium, and diffusion-weighted imaging) and a separate HRCT for workup.29 The cost-effectiveness of such a combination of imaging among patients needs to be evaluated.

Proper assessment of the extent of disease in MOE is crucial in planning the management and predicting the outcomes of the therapy. In early cases, differentiating MOE from severe external otitis is needed, and SPECT/CT is invaluable in such cases.30,31 Early diagnosis helps in the early treatment and improves the prognosis.

Conclusion

SPECT/CT is a more sensitive test than HRCT imaging in assessing the extent of disease in the skull base among patients with MEO. Proper staging of the disease with SPECT/CT scan is essential in deciding the course of treatment and is invaluable in counseling patients regarding the prognosis of the disease, giving them realistic expectations about the outcomes of therapy. This also convinces them of the need for prolonged antibiotic therapy. HRCT alone underestimates the real stage of the disease. Hence, we advocate SPECT/CT scan to be performed in all cases of clinically suspected MEO in the initial assessment of the extent of disease, in addition to HRCT imaging for collaborative findings. In clinically doubtful cases of MEO, SPECT/CT is suggested, even when HRCT imaging does not show any evidence of bone erosion.

Author Contributions

Ramawamy Balakrishnan, conception of the work, critical review of the manuscript including the revised manuscript and editing it, final approval and accountable for all aspects of the work; Pooja Dalakoti, collection of data and drafting of the paper and revision of the manuscript; approved the final manuscript and accountable for all aspects of the work; Dipak Ranjan Nayak, critical review for intellectual content of the work, review of the revised manuscript and edited it especially in the discussion area of the manuscript; approved the final resubmitted to be published manuscript and accountable for all aspects of the work; Kailesh Pujary, data analysis and reviewed the manuscript and edited the manuscript especially in the area of subjects and methods and results; approved the final resubmitted to be published manuscript and accountable for all aspects of the work; Rohit Singh, contributions to the design of the work and revised the manuscript and edited it with respect to the grammar and formatting; approved the final resubmitted to be published manuscript and accountable for all aspects of the work; Rajesh Kumar, critical review for the content of the work and edited the manuscript especially regarding the SPECT/CT scanning technique; approved the final resubmitted to be published manuscript and accountable for all aspects of the work.

Disclosures

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References


